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FINAL
GROUNDWATER
MONITORING REPORT
APRIL-MAY 2003

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
JET PROPULSION LABORATORY
4800 Oak Grove Drive
Pasadena, California 91109

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ACRONYMS/ABBREVIATIONS

1,1-DCA	1,1-dichloroethane
1,2-DCA	1,2-dichloroethane
1,1-DCE	1,1-dichloroethene
APCL	Applied Physics and Chemistry Laboratory
As	total arsenic
CCl_4	carbon tetrachloride
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
ClO_4^-	perchlorate
Cr	total chromium
Cr(VI)	hexavalent chromium
DHS	California Department of Health Services
DLR	detection level for the purpose of reporting
DQOs	data quality objectives
DTSC	Department of Toxic Substance Control
EPA	United States Environmental Protection Agency
GEOFON	GEOFON Incorporated
IAL	State Interim Action Level
JPL	Jet Propulsion Laboratory
LAWC	Lincoln Avenue Water Company
LCID	La Canada Irrigation District
LDC	Laboratory Data Consultants, Inc.
LFWC	Las Flores Water Company
MCLs	Maximum Contaminant Levels
μg/L	micrograms per liter
mg/L	milligrams per liter
MIBK	4-methyl-2-pentanone
mL	milliliter
MS	matrix spikes
MSD	matrix spike duplicates
MW	monitoring well
NASA	National Aeronautics and Space Administration
NDMA	N-nitrosodimethylamine
OU	operable unit
Pb	total lead
PCE	tetrachloroethene
PQL	practical quantitation limit

ACRONYMS/ABBREVIATIONS (CONTINUED)

QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
RCLWC	Rubio Canon Land & Water Company
RWQCB	California Regional Water Quality Control Board
SOTA	SOTA Environmental Technology, Inc.
TCE	trichloroethene
TDS	total dissolved solids
VOCs	volatile organic compounds
VWC	Valley Water Company
Westbay	Westbay Instruments, Inc.

EXECUTIVE SUMMARY

Presented in this report are the results of the April - May 2003 groundwater sampling event completed as part of the groundwater monitoring program at the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) under contract with Naval Facilities Engineering Command. This sampling event was conducted from April 17 through May 30, 2003.

During the April - May 2003 sampling event, groundwater samples were collected from 23 JPL monitoring wells, both on- and off-facility, and analyzed for volatile organic compounds (VOCs), metals (arsenic, lead, total chromium, and hexavalent chromium), perchlorate, and general water chemistry parameters including major anions/cations, total dissolved solids, and pH. Analyses for 1,4-dioxane and N-nitrosodimethylamine (NDMA) were also performed on select samples to evaluate its possible presence in groundwater beneath JPL. MW-2 has not been sampled since it was replaced with well MW-14 as a JPL sampling point.

All data collected were subject to data verification and all laboratory analytical data were validated pursuant to the Navy's Level IV quality assurance requirements. Some of the analytical data were qualified based on data validation reviews, in accordance with applicable United States Environmental Protection Agency (EPA) guidelines. No data were rejected for non-compliance with method requirements during the course of validation and no data were qualified as unusable. The analytical results are summarized below.

- Six on-facility wells and three off-facility wells contained concentrations of one or more of three VOCs (carbon tetrachloride, trichloroethene, and tetrachloroethene) that exceeded State or Federal Maximum Contaminant Levels (MCLs) for drinking water. Concentration contour maps generally indicate slow migration of the contaminant plumes over the last year.
- Perchlorate was detected in fourteen on-facility wells and five off-facility wells, with concentrations in four on-facility and three off-facility wells that exceeded the State Interim Action Level (IAL).
- Total chromium was detected in all 23 wells sampled; however, no concentrations exceeded the State and Federal MCL. Hexavalent chromium was detected in one on-facility well (MW-13). At this time, neither State nor Federal regulatory MCLs have been established for hexavalent chromium; however, the California Department of Health Services (DHS) lists hexavalent chromium as an unregulated chemical requiring monitoring and has established a detection level for the purpose of reporting (DLR) of 1.0 microgram per liter (µg/L).
- Trace concentrations of arsenic were detected in samples from seven on-facility and three off-facility wells. However, no arsenic concentrations were reported above the State or Federal MCLs, and lead was not detected in any sample.
- 1,4-Dioxane was reported at trace concentrations in samples from five on-facility wells, two of which exceed the IAL. At this time, neither State nor Federal MCLs have been established for 1,4-dioxane. DHS has established a DLR of 3.0 µg/L for 1,4-dioxane.
- Trace concentrations of NDMA were detected below the Action Level (0.01 µg/L) in one on-facility well. At this time, neither State nor Federal MCLs have been established for NDMA.

- Results from major anion and cation analyses (water chemistry) were used to identify the general water types beneath JPL. General water chemistry analyses indicate adequately defined and relatively stable groundwater chemistry beneath JPL. This finding is generally consistent with previously-reported data.

Groundwater gradients and flow directions before and after sampling activities were consistent with previous observations. Moderate increases in hydraulic head were measured in shallow wells and Westbay well screens in Aquifer Layer 1. Hydraulic head measurements were generally stable in Aquifer Layers 2 and 4, and generally decreased in Aquifer Layer 3. The water level fluctuations are likely due to several hydrologic phenomena operating simultaneously including, but not limited to, groundwater recharge, pumpage, and/or artificial recharge.

1.0 INTRODUCTION

This report summarizes the results from the April - May 2003 groundwater sampling event completed as part of the Groundwater Monitoring Program currently being conducted at the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL). This work is being performed by GEOFON, Inc. (GEOFON) under contract with Naval Facilities Engineering Command, Contract No. N68711-01-D-6008, D.O. No. 0010. The JPL Monitoring Program was initiated in 1996 in response to a request from the United States Environmental Protection Agency (EPA). The program began during the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Remedial Investigation of on-facility and off-facility groundwater at JPL. The purpose of the program is to monitor the elevation, flow direction, and quality of the groundwater beneath and adjacent to the JPL site.

The locations of the JPL groundwater monitoring wells are shown in Figure 1-1. Monitoring wells MW-3, MW-4, MW-11, MW-12, MW-14, and MW-17 through MW-24 are deep multi-port wells, each containing five screened intervals equipped with a Westbay Instruments, Inc. (Westbay) multi-port casing system. Monitoring wells MW-1, MW-5 through MW-10, MW-13, MW-15, and MW-16 are relatively shallow standpipe wells, each containing a single screened interval located just below the water table. A summary of the well construction details for the JPL groundwater monitoring wells is included in Table 1-1.

During the April - May 2003 event, GEOFON personnel collected samples from 23 on-facility and off-facility JPL monitoring wells. In addition, the water-level elevation at each well was measured on April 16, 2003 (prior to sampling), and on June 2-3, 2003 (after sampling) to evaluate groundwater flow directions and gradients. Water levels were not measured at MW-18 before or after sampling activities due to wellhead access restrictions.

JPL groundwater monitoring wells MW-1 through MW-24 (with the exception of former monitoring well MW-2) were sampled from April 17 through May 30, 2003. Monitoring well MW-2 has not been sampled since it was replaced with well MW-14 as a JPL sampling point. Samples from each well were collected and analyzed during this event in accordance with the sampling program that was approved by the EPA, Department of Toxic Substance Control (DTSC), and California Regional Water Quality Control Board (RWQCB).

All of the JPL groundwater samples were shipped to Applied Physics and Chemistry Laboratory (APCL) in Chino, California, for chemical analysis. APCL is certified by the California Department of Health Services and approved for use by the Naval Facilities Engineering Command, Quality Assurance/Quality Control (QA/QC) program. Sample collection procedures and sample analysis were conducted by GEOFON in accordance with the Work Plan for Performing a Remedial Investigation/Feasibility Study (Ebasco, 1993a), which was approved by the regulatory agencies. The following analyses were performed on the samples collected at JPL:

APRIL – MAY 2003 GROUNDWATER SAMPLE ANALYSIS

Analysis	Well (Screen)	EPA Method
Volatile Organic Compounds (VOCs)	All	524.2
Perchlorate (ClO_4^-)	All	314.0
Total Chromium (Cr)	All	200.8
Hexavalent Chromium [Cr(VI)]	All	7196
Total Lead (Pb)	All	200.8
Total Arsenic (As)	All	200.9
Total Dissolved Solids (TDS)	All	160.1
pH	All	150.1
Major Cations and Major Anions	All	Various
1,4-Dioxane	MW-4 (Screen 1 through 5), MW-5, MW 10, MW-13, MW-16, MW-17 (Screen 4), MW-24 (Screen 1)	8270
N-Nitrosodimethylamine (NDMA)	MW-4 (Screen 1), MW-13, MW-16, MW-17 (Screen 4), MW-24 (Screen 1)	1625M

In addition to groundwater samples, field QA/QC samples, including trip blanks, equipment blanks, duplicate samples, and a field blank, were collected for laboratory analyses. Sampling records for each shallow well and field data sheets for deep multi-port wells are included in Appendix A. Piezometric pressure profiling records for each deep multi-port well are included in Appendix B. Laboratory analytical reports and associated chain-of-custody forms are included in Appendix C, and data validation reports are provided in Appendix D.

Appendices E and F present summaries of analytical results for volatile organic compounds (VOCs) and metals, respectively, that were reported by others prior to GEOFON's initiation of the Long-Term Groundwater Monitoring activities at the JPL facility in January of 2003. Due to Navy's request, the format of the tables summarizing the results of the groundwater sample parameters was modified by GEOFON to present the data qualifiers as reported by the data validation company.

2.0 FIELD SAMPLING PROCEDURES

Two different procedures were used to collect groundwater samples at JPL, one designed for the shallow wells and the other for the deep multi-port wells. These procedures are outlined below.

2.1 Shallow Monitoring Wells

The sampling procedure described below was applied to all the shallow JPL monitoring wells, including MW-1, MW-5, MW-6, MW-7, MW-8, MW-9, MW-10, MW-13, MW-15 and MW-16.

- The primary equipment used to sample the shallow wells included dedicated 2-inch diameter Grundfos Redi-Flo2® pumps, a pump controller, and a 220-volt generator. All of the dedicated Grundfos Redi-Flo2® pump systems were previously decontaminated prior to their permanent installation. Details of the decontamination procedures for the Grundfos Redi-Flo2® pump systems are outlined in the Operable Unit (OU) OU-1 Field Sampling and Analysis Plan (Ebasco, 1993b).
- Prior to sample collection, the water in each shallow well casing was purged (by pumping at about 2.5 gallons per minute) to remove groundwater that may have been exposed to the atmosphere and thus may not be representative of undisturbed aquifer conditions. This purged groundwater was discharged into 500 or 1,000-gallon polyethylene storage tanks for subsequent disposal by GEOFON in accordance with Federal, State, and local regulations.
- Temperature, pH, electrical conductivity, and turbidity of the water removed from each well were monitored during purging. Pursuant to the approved work plan (Ebasco, 1993b), a minimum of three casing volumes of water was purged and temperature, pH, electrical conductivity and turbidity were monitored for stabilization. When two successive measurements, made approximately 5 minutes apart, were within 10 percent of each other, groundwater samples were collected using the dedicated pump. During sampling for VOCs, the pumping rate was reduced to minimize sample agitation and volatilization. All information concerning sampling was noted on the Well Development/Well Sampling Log forms included in Appendix A.
- All sample bottles were filled completely without overflowing, capped, labeled, and immediately placed in a cooler with ice. Samples collected for VOCs had zero headspace.

- Calibration, or standardization of the field instruments used to measure temperature, pH, electrical conductivity, and turbidity, was performed according to the manufacturer's specifications at the beginning of each sampling day.

2.2 Deep Multi-Port Monitoring Wells

Sampling of the deep multi-port monitoring wells at JPL required specialized sampling equipment manufactured by Westbay Instruments, Inc. (Westbay). This equipment included a pressure profiling/sampling probe with a surface control unit. To ensure proper use, field personnel using this equipment were trained by Westbay personnel. Copies of the detailed operations manuals for the Westbay pressure profiling/sampling probe are included in the OU-1 and OU-3 Field Sampling and Analysis Plans (Ebasco, 1993b; 1994).

The Westbay sampling probe and sample-collection bottles were decontaminated prior to sampling each screened interval in the deep multi-port wells according to the following procedures:

- Each 250-mL stainless-steel sample-collection bottle was washed in a solution of non-phosphate detergent (Liquinox®) and distilled water, followed by a solution of an acidic detergent (Citranox®) and distilled water.
- Each bottle was rinsed with distilled water.
- The interior surfaces of the Westbay sampling probe, and the hoses and valves associated with the Westbay sample bottles were decontaminated by forcing several volumes of a solution of Liquinox® and distilled water through them, followed by forcing several volumes of a solution of Citranox® and distilled water. A final rinse with distilled water was carried out. Each of these decontamination procedures was completed using clean plastic spray bottles used only for this purpose.

Purging before sampling is not required in the deep multi-port monitoring wells because the groundwater samples were collected directly from the aquifer, thus ensuring that the groundwater samples were not exposed to the atmosphere. However, at each screened interval, an initial sample was collected in order to check temperature, pH, electrical conductivity, and turbidity in the field. Samples for laboratory analysis were then collected and transferred to sample containers as described in Section 2.1. Results of the field analyses were recorded on groundwater sampling field data sheets (Appendix A). Calibration of field instruments was carried out according to procedures described previously.

2.3 Field Quality Assurance/Quality Control Samples

Field QA/QC samples were collected to verify the quality of sampling procedures. The field QA/QC program included the collection of duplicate samples, equipment blanks, trip blanks, and source blanks. Laboratory QA/QC samples were used by the laboratory according to analytical method requirements.

Duplicate samples for VOCs, metals, and perchlorate (ClO_4^-) analyses were collected from deep multi-port monitoring wells MW-3 (Screen 2), MW-4 (Screen 4), MW-12 (Screen 3), MW-14 (Screen 3), MW-18 (Screen 4), MW-20 (Screen 1), and MW-24 (Screen 2). One duplicate sample for 1,4-dioxane analysis was collected from groundwater monitoring well MW-4 (Screen 2).

Matrix-Spike (MS) and Matrix-Spike Duplicate (MSD) samples were collected for 10% of samples that were analyzed for VOCs, perchlorate, and metals. These samples were used for laboratory QA/QC requirements.

One equipment blank was collected from the Westbay sample-collection bottles during each day of sampling the deep multi-port wells. Equipment blanks consisted of distilled water that was passed through the sampling equipment after the equipment was decontaminated. Equipment blanks were analyzed for the same constituents as the groundwater samples, except for cations and anions, total dissolved solids, and pH, to identify potential cross contamination due to inadequate decontamination. Because only dedicated sampling equipment was used, equipment blanks were not collected during sampling of the shallow wells.

A trip blank, consisting of American Society for Testing Materials Type II water placed in two 40-mL glass vials by the laboratory, was transported with the empty sample bottles to the field and back to the laboratory with the groundwater samples. One trip blank was submitted for VOC analysis with each shipment of groundwater samples to the laboratory. Trip blanks were used to identify potential cross contamination of groundwater samples during transport.

During this sampling event, one source blank was collected on April 21st. The source blank was used to evaluate whether the source water or sample containers may have affected the analytical results by cross contamination. The source blanks, consisting of sample bottles filled with distilled water, were analyzed for VOCs.

3.0 ANALYTICAL RESULTS

The groundwater samples collected during this sampling event were analyzed for the following:

- Volatile Organic Compounds (VOCs)
- Total Chromium (Cr)
- Hexavalent Chromium [Cr(VI)]
- Total Lead (Pb)
- Total Arsenic (As)
- Total Dissolved Solids (TDS)
- pH
- Major Cations and Major Anions
- Perchlorate (ClO_4^-)
- 1,4-Dioxane
- N-Nitrosodimethylamine (NDMA)

Groundwater samples collected from seven locations [MW-4 (all Screens), MW-5, MW-10, MW-13, MW-16, MW-17 (Screen 4), and MW-24 (Screen 1)] during the April – May 2003 sampling event were analyzed for 1,4-dioxane. Groundwater samples from five locations [MW-4 (Screen 1), MW-13, MW-16, MW-17 (Screen 4), and MW-24 (Screen 1)] were analyzed for NDMA. A summary of the samples collected and the analyses performed on each sample is presented in Table 3-1. Analytical laboratory reports and associated chain-of-custody forms are included in Appendix C.

The aquifer beneath JPL was divided into four aquifer layers based primarily on correlations interpreted from lithologic cross sections (Foster Wheeler, 2000). Table 3-2 provides a list of the JPL Westbay monitoring well screens and their corresponding aquifer layers. Concentrations of carbon tetrachloride (CCl_4), trichloroethene (TCE), tetrachloroethene (PCE), and perchlorate (ClO_4^-) reported during this event are presented for each aquifer layer in Figures 3-1 through 3-12.

3.1 Volatile Organic Compounds

Groundwater samples collected during the April – May 2003 sampling event were analyzed for over 60 different VOCs in accordance with EPA Method 524.2. Results of the analyses for VOCs in the April - May 2003 samples are summarized in Table 3-3 along with the State and Federal Maximum Contaminant Levels (MCLs) for drinking water as listed in Title 22 of the California Code of Regulations and in the EPA Health Advisory Guidelines.

A small number of compounds were detected in the JPL samples, and three VOCs (CCl_4, TCE, and PCE) were found in one or more wells at concentrations that exceeded State and/or Federal MCLs. The concentrations of CCl_4, TCE, and PCE detected in each aquifer layer were contoured on site maps to show the spatial distribution of each constituent (Figures 3-1 through 3-9). The analytical results for compounds that exceeded MCLs are discussed below.

- Concentrations of CCl_4 in excess of the State MCL [0.5 micrograms per liter (μg/L)] were reported in samples from five on-facility wells [MW-7, MW-12 (Screens 3, 4, and 5), MW-13, MW-16, and MW-24 (Screens 1 and 2)] and two off-facility wells [MW-17 (Screen 3) and MW-18 (Screen 4)]. The Federal MCL (5.0 μg/L) was exceeded in MW-7, MW-17, and MW-24. The highest concentration of CCl_4 was reported in well MW-7 (73.7 μg/L).
- TCE was detected in nine on-facility wells and four off-facility wells. Reported TCE concentrations exceeded the State and Federal MCL (5.0 μg/L) in three on-facility wells (MW-7, MW-10, and MW-13) and one off-facility well [MW-17 (Screen 4)]. The highest concentrations of TCE were reported in samples from on-facility wells MW-10 (11.2 μg/L) and MW-13 (9.2 μg/L).
- PCE was detected in eight on-facility and four off-facility wells. The State and Federal MCL (5.0 μg/L) was exceeded only in on-facility well MW-7 (9.9 μg/L) and off-facility well MW-21 (5.2 μg/L in Screen 4 and 12.3 μg/L in Screen 5).

A summary of the VOC results compiled from the long-term sampling events that have been completed to date is provided in Table 3-4. Nine chemicals have been most commonly reported with concentrations above the laboratory detection limits [CCl_4, TCE, PCE, 1,1-dichloroethane (1,1-DCA), 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethene (1,1-DCE), Freon 113, chloroform, and ClO_4^-)]. The concentrations of these compounds versus time were plotted, if at any time they exceeded their respective MCL from August/September 1996 through April - May 2003. The plots are presented in Figures 3-13 through 3-59.

Additional data regarding VOC concentrations in samples collected from nine municipal production wells in the vicinity of JPL were obtained from the California Department of Health Services (DHS) Drinking Water Program (DHS, 2003). The most recently available analytical results were compiled for samples collected from municipal and private drinking water wells owned and operated by La Canada Irrigation District (LCID), Lincoln Avenue Water Company (LAWC), Valley Water Company (VWC), and Las Flores Water Company (LFWC). The drinking water data are summarized in Table 3-5 and presented in the concentration contour maps for CCl_4, TCE, and PCE in Figures 3-2, 3-3, 3-5, 3-6, 3-8, and 3-9.

The most recent samples from seven drinking water wells exceeded the State MCLs for CCl_4, TCE, or PCE. CCl_4 was detected at LAWC Well #5 (0.73 μg/L), exceeding the State MCL (0.5

μg/L). TCE was detected in all of the LAWC wells and in VWC Well #2 and Well #3, but only reported above the MCL (5.0 μg/L) at LAWC Well #5 (17.0 μg/L). PCE was detected in eight of the nine municipal wells, exceeding the MCL (5.0 μg/L) at VWC Well #2 (8.7 μg/L) and during several sampling events at LFWC Well #2 (maximum concentration of 13.0 μg/L) (DHS, 2003).

3.2 Perchlorate

ClO_4^- analyses were conducted on groundwater samples from the April - May 2003 event using ion chromatography modified EPA Method 314.0 and the results are summarized in Table 3-3. No MCLs have been established for ClO_4^-; however the California Department of Health Services (DHS) has established a State Interim Action Level (IAL) of 18 μg/L. ClO_4^- was detected in fourteen on-facility wells and five off-facility wells. ClO_4^- concentrations exceeded the IAL in four on-facility wells (MW-7, MW-13, MW-16, and MW-24) and in three off-facility wells (MW-17, MW-18, and MW-20).

The highest levels of ClO_4^- were reported in samples from MW-7 (5,560 μg/L), MW-16 (1,810 μg/L), and MW-24 (854 μg/L in Screen 1). ClO_4^- concentrations have been contoured in Figures 3-10, 3-11, and 3-12 for aquifer layers 1, 2, and 3, respectively.

Additional data regarding ClO_4^- concentrations in samples collected from three municipal production wells in the vicinity of JPL were obtained from the DHS Drinking Water Program (DHS, 2003). The most recently available analytical results were compiled for samples collected from municipal and private drinking water wells owned and operated by Rubio Canon Land & Water Company (RCLWC) and LFWC. ClO_4^- was detected only at LFWC Well #2; however, this result did not exceed the IAL (18 μg/L) (DHS, 2003). The drinking water data for ClO_4^- are summarized in Table 3-5 and are presented in the concentration contour maps in Figures 3-10 through 3-12.

3.3 Metals

Groundwater samples collected during the April - May 2003 event were analyzed for the following metals: arsenic, lead, total chromium, and hexavalent chromium. The results of the metals analyses are presented in Table 3-6, and are summarized below.

- Arsenic was detected in seven on-facility wells (MW-3, MW-4, MW-9, MW-15, MW-16, MW-23, and MW-24) and three off-facility wells (MW-17, MW-19, and MW-21), with concentrations ranging from 0.0016 milligrams per liter (mg/L) to 0.0044 mg/L. None of the reported concentrations exceeded the State and Federal MCL of 0.05 mg/L.

- Lead was not detected in any samples collected during the April – May 2003 event.
- Total chromium was detected in all 23 wells sampled during this monitoring event. None of the reported concentrations exceeded the State MCL (0.05 mg/L) or Federal MCL (0.10 mg/L).
- Hexavalent chromium was detected in one on-facility well, MW-13, at a concentration of 0.024 mg/L. At this time, neither State nor Federal regulatory agencies have established an MCL for hexavalent chromium.

Table 3-7 presents a summary of metals data from all quarterly sampling events completed to date during the long-term monitoring program.

3.4 1,4-Dioxane and NDMA

During the April - May 2003 event, groundwater samples from seven locations [MW-4 (all Screens), MW-5, MW-10, MW-13, MW-16, MW-17 (Screen 4), and MW-24 (Screen 1)] were analyzed for 1,4-dioxane using EPA Method 8270. Samples from these seven wells have historically contained the highest-reported concentrations of VOCs at JPL. 1,4-dioxane was detected in five of the seven wells analyzed: MW-4 [Screen 2 (1.0 µg/L) and Screen 3 (0.4 µg/L)], MW-10 (1.0 µg/L), MW-13 (2.5 µg/L), MW-16 (6.3 µg/L) and MW-24 [Screen 1 (3.6 µg/L)]. 1,4-Dioxane concentrations exceeded the current drinking water IAL (3.0 µg/L) at two wells [MW-16 and MW-24 (Screen 1)]. At this time, neither State nor Federal MCLs have been established for 1,4-dioxane.

Groundwater samples from five locations [MW-4 (Screen 1), MW-13, MW-16, MW-17 (Screen 4), and MW-24 (Screen 1)] were analyzed for NDMA using modified EPA Method 1625. NDMA was reported in one groundwater sample, MW-13 (0.00076 µg/L); however, this result did not exceed the current drinking water Action Level (0.01 µg/L). No State or Federal MCLs have been established for NDMA. The results for 1,4-dioxane and NDMA are presented in Table 3-8.

3.5 Quality Assurance/Quality Control

Review of the QA/QC data provided with the laboratory analytical results indicates that all of the analytical results obtained from April - May 2003 samples are acceptable for their intended use of characterizing aquifer quality. Surrogate compound, matrix and blank spike, and method blank results were used by the laboratory to determine the accuracy and precision of the analytical techniques with respect to the JPL groundwater matrix, and to identify anomalous results due to laboratory contamination or instrument malfunction. In addition to laboratory QA/QC samples, GEOFON personnel collected QA/QC samples in the field in general accordance with the Quality Assurance Project Plan (QAPP) (Ebasco, 1993c). The field QA/QC samples included duplicate samples, equipment rinsate blanks, trip blanks, and a source blank.

Duplicate samples were used to evaluate the precision of the laboratory analyses. Duplicate samples for VOCs, metals, and ClO_4^- analyses were collected from deep multi-port monitoring wells MW-3 (Screen 2), MW-4 (Screen 4), MW-12 (Screen 3), MW-14 (Screen 3), MW-18 (Screen 4), MW-20 (Screen 1), and MW-24 (Screen 2). One duplicate sample for 1,4-dioxane analysis was collected from the deep multi-port monitoring well MW-4 (Screen 2). All of the analytical results for the duplicate samples were comparable to the results of the original groundwater samples (Tables 3-3, 3-6, and 3-8).

Equipment rinsate blanks were collected each day non-dedicated sampling equipment was used. The equipment rinsate blanks, consisting of distilled water run through the sampling equipment after decontamination, were analyzed for all contaminants of concern to monitor possible cross-contamination of samples due to inadequate decontamination. 4-Methyl-2-pentanone (MIBK), total chromium, and lead were detected in seven, six, and four equipment rinsate blanks, respectively (Table 3-9).

A laboratory-prepared trip blank, consisting of reagent-grade water placed in VOA vials and transported with the sample bottles to the field, was submitted to the laboratory with each daily shipment of groundwater samples. Trip blanks were used to help identify cross-contamination of groundwater samples during transport and/or deficiencies in the laboratory bottle cleaning and sample handling procedures. MIBK and m,p-xylene were detected at estimated concentrations below the practical quantitation limit (PQL) of the laboratory. Naphthalene was detected in one trip blank at a concentration of 1.4 µg/L (TB-10-5/6/03). Methylene chloride was detected in three trip blanks with a highest concentration of 3.6 µg/L. Table 3-9 presents a summary of contaminants detected in quality control samples collected during the April - May 2003 sampling event.

One source blank was collected during this sampling event, consisting of sample bottles filled with the distilled water used for decontamination and equipment rinsate blanks. The source blank was used to assess the quality of water used to decontaminate sampling equipment. No contaminants were detected in the source blank.

4.0 GENERAL WATER CHEMISTRY

As part of this groundwater monitoring event, groundwater samples were analyzed for major cations and anions in an effort to further understand the natural water chemistry of the groundwater beneath and adjacent to JPL. All groundwater samples collected during the April - May 2003 event were analyzed for major cations (Ca^{2+}, Fe^{2+}, Mg^{2+}, Na^{+}, and K^{+}), major anions (Cl^{-}, SO_4^{2}-, NO_3^{-}, CO_3^{2-} and HCO_3^{-}), pH, alkalinity, and TDS. The water chemistry results for this quarterly sampling event are summarized in Table 4-1.

4.1 Analytical Results

To illustrate the relative proportions of the major cations and anions in each groundwater sample, the water chemistry results from the April - May 2003 event have been plotted as Stiff diagrams (Figures 4-1, 4-2, and 4-3). Based on previous review of the water chemistry data, groundwater at JPL has been divided into three general types, based on the predominant cation and anion, and the occurrence of other ions. These general water types include:

Type 1. Calcium-bicarbonate groundwater. Groundwater with Ca^{2+} as the dominant cation and HCO_3^{-} as the dominant anion.

Type 2. Sodium-bicarbonate groundwater. Groundwater with Na^{+} as the dominant cation and HCO_3^{-} as the dominant anion.

Type 3. Calcium-bicarbonate/chloride/sulfate groundwater. Groundwater with Ca^{2+} as the dominant cation and HCO_3^{-} as the dominant anion, but with relatively elevated Cl^{-}, and SO_4^{2-} concentrations.

In addition to the general water types, the previous analytical data suggest that these water types mix or blend with one another, creating “intermediate” water types. For example, water Types 1 and 2 can mix to create a 1+2 or a 2+1 type, where the first number indicates the general water type that is predominant in the mixture. The Stiff diagrams presented in Figures 4-1 through 4-3 contain some graphical representations of these “intermediate” water types.

Water Type 1, the calcium-bicarbonate water type, was found to be the most common water type at JPL during the April - May 2003 sampling event. In general, it was found at relatively shallow depths in wells located around the Arroyo Seco. Water Type 2, the sodium-bicarbonate water type (including associated blends) was typically found in the deeper well screens of both the on-site and off-site multi-port wells. Type 3 groundwater, the calcium-bicarbonate/chloride/sulfate water type, was prevalent in the shallower screens of the monitoring wells located upgradient and to the south of the JPL facility. A list of water types and JPL monitoring wells in which they occur is provided in Table 4-2.

4.2 Quality Assurance/Quality Control

To evaluate the general quality of the water chemistry data, two independent geochemical quality control checks of the analytical results from the April - May 2003 samples were performed. These checks included calculation of total ion-charge balances, and comparison of errors in the measured TDS values or the presence of other cations/anions. The results of these checks for this groundwater sampling event are presented in Table 4-3.

Charge balances are expressed as the percent difference between the sum of the equivalent weights of all of the anions and cations analyzed (Freeze and Cherry, 1979). The ideal range for charge balances is ±5 percent, although charge balance errors up to ±10 percent are considered acceptable. The charge balances for thirty (30) of the 75 samples analyzed for major anions and cations during this sampling event are within the ideal range (±5 percent) for all wells. Thirty-two (32) of the samples had charge balances between 5 and 10 percent, and thirteen (13) samples had a charge balance over 10 percent. This indicates that 83% of the results are acceptable for their intended use.

TDS results were used to verify that all of the important water chemistry constituents were analyzed by comparing the measured laboratory TDS value to a calculated TDS value (calculated as the sum of the major anion and cation concentrations) for each sample. Under ideal conditions, the ratio of the measured to calculated TDS values should range from 0.8 to 1.2 (Oppenheimer and Eaton, 1986). The ratio of measured to calculated TDS values for the April - May 2003 water chemistry results fell within the ideal range (0.8 to 1.2) for 64 of the 75 sets of water chemistry analyses performed (Table 4-3). The TDS ratios for the remaining 11 sets of data fell slightly outside this ideal range, which suggests possible minor analytical errors and/or the presence of other cations/anions. However, all of the data are considered suitable for their intended use of identifying differences in water chemistry across the site.

5.0 DATA VERIFICATION AND VALIDATION

The purpose of data verification and validation is to assure that the data collected meet the data quality objectives (DQOs) outlined in the Quality Assurance Project Plan of the Groundwater Monitoring Plan (Ebasco, 1993c). The process is intended to ensure that the data are of sufficient quality for use in meeting the objectives outlined in the Groundwater Monitoring Plan.

5.1 Data Verification

All data collected were subjected to data verification. In general, verification identifies non-technical errors in the data package that can be corrected (e.g., typographical errors). Data verification included proofreading and editing hard-copy data reports to assure that data correctly represent the analytical measurement. Data verification also included verifying that the sample identifiers on laboratory reports (hard copy) matched those on the chain-of-custody record.

5.2 Data Validation

Data validation is a systematic process that is used to interpret, define, and document analytical data quality and determine whether the data quality is sufficient to support the intended use(s) of the data. Validation of a data package includes reconstruction of sample preparation, analysis of the raw data, reconciliation of the raw data with the reduced results, identification of data anomalies, and qualification of data to identify data usability limitations.

Data validation was performed by an independent subcontractor, Laboratory Data Consultants, Inc., Carlsbad, CA (LDC). One hundred percent of all data analyzed by a fixed-base analytical laboratory (APCL) were validated. Ten percent of the data were subjected to Level IV quality assurance requirements of the Navy (Navy, 1996 and Navy, 1999). The data were further evaluated to help ensure suitability and usability for the purpose of the groundwater monitoring report.

5.3 Data Validation Qualifiers

Analytical data were qualified based on data validation reviews. For chemical data, qualifiers were assigned in accordance with the applicable EPA National Functional Guidelines for Data Validation (EPA, 1994a and 1994b). Individual laboratory data flags can be found in Appendix D. No data were rejected for non-compliance with method requirements during the course of validation.

6.0 WATER LEVEL MEASUREMENTS

Water level measurements were recorded before the sampling event on April 16, 2003, and after the sampling event on June 2-3, 2003, to evaluate groundwater flow directions and gradients beneath and adjacent to JPL. Water levels in the shallow wells were measured using a Solinst® water level meter. In the deep multi-port wells, the hydraulic head at each sampling port was measured with a Westbay pressure-transducer probe.

Water table elevation measurements taken before sampling are provided in Table 6-1 and have been contoured in Figure 6-1. Water table elevation measurements taken after sampling are provided in Table 6-2 and have been contoured in Figure 6-2. The hydraulic heads measured at each deep multi-port well screen before and after sampling are presented graphically in Figure 6-3. The piezometric pressure-profile records for the deep wells are included in Appendix B.

Water levels in the shallow wells rose roughly 0.1 to 20.6 feet during the April - May 2003 event, rising an average of about 5.9 feet. This increase was slightly higher than the increases measured in Westbay wells screened in Aquifer Layer 1, which averaged about 2.8 feet and ranged from -12.4 to 20.6 feet. Water levels in Aquifer Layer 1 generally rose during this event. Hydraulic head elevations in Westbay wells screened in Aquifer Layer 2 ranged from about -28.1 to 2.6 feet with an average of about -1.1 feet, while those screened in Aquifer Layer 3 ranged from about -17.0 to 0.2 feet and averaged -3.9 feet. Water levels in Aquifer Layer 2 were generally stable, and water levels in Aquifer Layer 3 generally decreased during this event. The most notable increases in hydraulic head measured during the April - May 2003 event were seen in Aquifer Layer 1, shallow wells MW-1, MW-7, MW-8, MW-13, and MW-16. The most notable decreases, as shown in Figure 6-3, were seen in Aquifer Layers 2 and 3, deep wells MW-14, MW-20, and MW-21. The only well screen in Aquifer Layer 4 [MW-20 (Screen 5)] rose 0.3 feet during this event.

Water level fluctuations can result from a wide variety of hydrologic phenomena, some natural and some induced by man. It is likely that several of these phenomena are operating simultaneously including, but not limited to:

- Groundwater recharge/infiltration to the water table,
- Air entrapment during groundwater recharge,
- Groundwater pumpage, and/or
- Artificial recharge from the spreading grounds.

As depicted in Figures 6-1 and 6-2, the estimated groundwater flow direction both before and after sampling was generally consistent with previous observations. The flow was primarily to the south-southwest through the eastern portion of JPL and to the east-southeast in the southwest portion of JPL, Arroyo, and plain. The estimated groundwater gradients measured both at the beginning and end of the event ranged from about 0.2 feet per foot near MW-9, at the northern end of the Arroyo, to 0.005 feet per foot across the Arroyo and plain.

7.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are based upon interpretation of analytical data and field measurements collected during the April - May 2003 event and previous events of the JPL Monitoring Program:

- The chemical plumes beneath JPL are adequately defined and relatively stable. The concentration contour maps generally indicate slow migration of the contaminant plumes over the last year. Comparison of the results with the previous monitoring events did not reveal any significant increases or decreases in contaminant concentrations, with the exception of ClO_4^-, discussed below. In summary, the April - May 2003 analytical results indicate the following:

  - ♦ Three VOCs (CCl_4, TCE, and PCE) were detected in one or more monitoring wells at concentrations above the State or Federal MCLs for drinking water.

  - ♦ ClO4– concentrations exceeded the State IAL for drinking water in four on-facility wells. The highest levels of perchlorate were reported in samples from MW-7, MW-13, MW-16, and MW-24.

  - ♦ Total chromium was detected in all 23 wells sampled; however, no concentrations exceeded the State or Federal MCLs. Hexavalent chromium was detected in one well. At this time, neither State nor Federal MCLs have been established for hexavalent chromium.

  - ♦ Very low (trace) concentrations of arsenic were detected in seven on-facility wells (MW-3, MW-4, MW-9, MW-15, MW-16, MW-23, and MW-24) and three off-facility wells (MW-17, MW-19, and MW-21). No arsenic concentrations were reported above the State or Federal MCLs, and lead was not detected in any sample.

  - ♦ 1,4-Dioxane was detected at trace concentrations in five on-facility wells MW-4, MW-10, MW-13, MW-16, and MW-24 (Screen 1). Two samples [MW-16 and MW-24 (Screen 1)] exceeded the current drinking water IAL (3.0 µg/L) for 1,4-dioxane. At this time, neither State nor Federal MCLs have been established for 1,4-dioxane.

  - ♦ NDMA was detected at trace concentrations, below the current drinking water Action Level (0.01 µg/L), in on-facility well MW-13. At this time, neither State nor Federal MCLs have been established for NDMA.

- General water chemistry analyses indicate adequately defined and relatively stable groundwater chemistry beneath JPL, which is generally consistent with the previously-reported data (SOTA, 2001, 2002 and Foster Wheeler, 2000).
- Moderate increases in hydraulic head were measured during this event in shallow wells and Westbay well screens in Aquifer Layer 1. Hydraulic head measurements were generally stable in Aquifer Layers 2 and 4, and generally decreased in Aquifer Layer 3. The water level fluctuations are likely due to several hydrologic phenomena operating simultaneously including, but not limited to, groundwater recharge, pumpage, and/or artificial recharge.
- Groundwater gradient maps prepared using the April - May 2003 water level measurements indicate that groundwater gradients and flow directions are generally consistent with previous observations (SOTA, 2002, 2001 and Foster Wheeler, 2000).

8.0 REFERENCES

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